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PARTICLE ASSOCIATED CONTAMINANT TRANSPORT IN THE YAMASKA RIVER

by

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ABSTRACT

For proper modelling of contaminant transport in rivers, the knowledge on partitioning of contaminants between suspended particles including bacteria, and the dissolved phase is an essential prerequisite. The adsorption of contaminant onto the suspended matter is influenced by parameters such as particle size distribution, bacterial content, etc. To gain a better understanding of the effects of particle size distribution and the bacterial content on the contaminant adsorption process, laboratory studies were initiated using natural suspended matter obtained from a highly contaminated river in the province of Quebec in Canada (Yamaska River). The samples from the river were subjected to particle size distribution analysis using a laser particle size analyser. The different size fractions of the sample seperated using fractionation technique were subjected to (a) bacteriological analysis and (b) contaminant/ particles interaction to establish the nature and extent of contaminant binding efficiency.

Data indicate that the 20-40 μm particle size fraction is the predominant component in the Yamaska River water and exhibits the maximum contaminant binding efficiency. The maximum removal rate of contaminant occurs within the 24 h period. The active fraction is also found to be rich in organic matter. The significance of the organic rich active fraction in the transport of contaminants is discussed.

RÉSUMÉ

Afin de pouvoir modéliser adéquatement le transport fluvial des contaminants, il est nécessaire de bien comprendre la séparation des contaminants entre les particules en suspension, y compris les bactéries, ainsi que la phase dissoute. L'adsorption d'un contaminant par les matières en suspension est fonction de certains paramètres, notamment la distribution granulométrique, la teneur en bactéries, etc. Afin de mieux comprendre les effets de la distribution granulométrique et de la teneur bactérienne sur le processus d'adsorption des contaminants, des études en laboratoire sur des matières en suspension naturelles prélevées dans une rivière extrêmement contaminée de la province de Québec au Canada, la rivière Yamaska, ont été entreprises. Les échantillons provenant de la rivière ont été soumis à une analyse de la distribution granulométrique à l'aide d'un appareil d'analyse granulométrique à laser. Les diverses fractions de l'échantillon, séparées par la technique de fractionnement, ont été soumises à : a) une analyse bactériologique et b) une interaction contaminants/particules, afin d'établir la nature et l'importance de la capacité de fixation des contaminants.

Les données indiquent que la fraction 20-40 um est la principale composante de l'eau de la rivière Yamaska et qu'elle présente l'efficacité maximale de fixation des contaminants. Le transport maximal des contaminants se produit au cours d'une période de 24 heures. La fraction active est également riche en matière organique. Le rôle de la fraction active riche en matière organique dans le transport des contaminants est également traité.

MANAGEMENT PERSPECTIVE

The role of suspended particulate matter (inorganic and organic) on the transport of contaminants in river systems is well recognized. The effect of particle size distribution and organic matter, on the other hand, is not clearly understood. The present study dealing with the suspended organic aggregate particles of the Yamaska River shows some interesting results. The study indicates that the highest percentage of microbial organic matter is associated with the predominant size fraction of the suspended particles. This fraction has also exhibited the highest binding capacity to model contaminants. This means that the bulk of the contaminant transport is associated with the organic rich predominant fraction and models of contaminant transport should focus their attention on the transport characteristics of predominant size fraction. General applicability of such results to other river systems should be investigated.

PERSPECTIVE-GESTION

Le rôle de la matière particulaire en suspension (organique et inorganique) sur le transport des contaminants dans les systèmes fluviaux est reconnu. Par contre, l'effet de la distribution granulométrique et de la matière organique n'est pas bien compris. L'étude présentée ici, qui porte sur les agrégats de particules organiques en suspension dans la rivière Yamaska, a donné quelques résultats intéressants. Ainsi, d'après l'étude, le pourcentage le plus élevé de matière organique microbienne est associé à la fraction granulométrique dominante des particules en suspension. Cette fraction présente également la capacité de fixation la plus élevée pour les contaminants modèles. Cela veut dire que la majeure partie du transport de contaminants est associée à la fraction prédominante riche en matière organique et que les modèles du transport de contaminants devraient mettre l'accent sur les caractéristiques du transport de la fraction granulométrique prédominante. L'extrapolation de ces résultats à d'autres systèmes fluviaux devrait être étudiée.

INTRODUCTION

There is an increased need for basic research to assess the environmental behaviour of contaminants to ensure the continued improvement in the prediction of their fate. The assessment requires the use of several types of information including partitioning behaviour of contaminants between solids and liquid phases. The sorption of contaminants onto suspended particles have been shown to be influenced by a number of factors such as particle size distribution and bacteria among others (Blachford and Day, 1988). Adhesion of bacteria to particles surface plays a vital role in the behaviour of contaminant-bacterial aggregates (Fletcher and Floodgate, 1973; Marshall and Cruickshank, 1973; Marshall, 1986). To gain more understanding of the partitioning behaviour of contaminant between liquid and suspended particles including bacteria in fluvial systems, laboratory studies were initiated using a water soluble dye and natural suspended aggregates collected from a highly polluted part of the Yamaska River in the Province of Quebec, Canada (Figure 1).

In this article we present data on the nature of particle size distribution in the river water, bacterial content of different particle size ranges, contaminant binding affinity of different particle sizes and the nature of particles associated with the contaminant transport processes. Some of the implications of the active fractions associated in the fluvial transport processes are also discussed.

MATERIALS AND METHODS

The Yamaska River situated in the eastern township of Quebec, receives discharges from major textile industries in addition to pesticides and domestic and farm wastes. During June and August 1988, a 5 L surface water sample (grab sample) was collected from Station #5 (Figure 1). The suspended particles were filtered out of water samples and were subjected to particle size distribution analysis using a laser particle size analyser manufactured by Malvern Instruments Ltd. This system comprises a light source which contains 3 mV laser, a receiving optics assembly and an electronic circuitry to interphase with a microcomputer (Bale and Morris, 1987). Particle size distribution of the samples was derived from measurements of the near-forward Fraunhofer diffraction spectrum that is provided by a particle group randomly distributed in a sample cell mounted in the beam path between the laser source and the detector array.

Particle size fraction of the river water samples was performed using cascade sieving procedure (Munawar et al., 1983). Suspended particulate matter retained on each of the following filters were resuspended in low response water. Particles retained on:

(a) 88 µm represented particles in the >88 µm range

(b) 64 µm represented particles in the 64-88 µm range

(c) 40 µm represented particles in the 40-64 µm range

(d) 20 µm represented particles in the 20-40 µm range

(e) 8 µm represented particles in the 8-20 µm range

(f) 3 µm represented particles in the 3- 8 µm range

These different ranges of particles were analysed for their bacterial content using the acridine orange direct microscopic counting procedure (Rao et al., 1984) using 0.1 µm nucleopore filter and phase contrast microscope. A 1 ml of 1/10 dilution of each of the fractions was thoroughly homogenized (Marxsen, 1988) using a vortex mixer at #10 speed setting for 1 min. This procedure facilitated uniform dispersion of bacteria from aggregates. This uniform mixture was immediately subjected to membrane filtration (0.2 µm nucleopore membrane) and staining with acridine orange for 3 min. Total microscopic counts were made using the phase contrast illumination (Rao et al., 1984).

A 200 mL solution containing each of these different fractions in low response water were treated with 5 ppm solution of contaminant dye acid orange-60 and/or Basic violet-1 in order to establish the nature and extent of binding efficacy of these fractions of particles of bacterial aggregates. (These 2 contaminant dyes were used as model contaminants because of their presence in the waters of the Yamaska River). The sorption experiments were performed in the dark in order to exclude photodegradation interferences of these photosensitive dyes. The concentrations of the dyes in the reaction mixtures were determined spectrophotometrically at 24 h intervals after centrifugation (500xg for 10 min.). The absorbances maximum for Basic violet-1 at 586 nm and 273 nm for acid orange-60 were used to determine the dye concentration. The results were calculated and expressed as mg dye removed by mg (dry wt.) particles in each of these fractions.

RESULTS AND DISCUSSIONS

It has been indicated that large portions of fluvial transport of particles in Canada occurs in the form of suspended material particles sizes in the 2 µm-62 µm range (Blachford and Day, 1988). Suspended particles ordinarily composed of organic and inorganic materials, and organic aggregates are composed of materials from plants and animals in various stages of decomposition, thus providing nutrient base for microbes. For the Yamaska River the particle size distribution analysis (indicated in Table 1) as determined by the Malvern particle size analyser indicates that 67% (by volume) of the suspended particles were below 40 µm size (3 µm-40 µm). The value for June is 76.5% and for August is 57.7%. The 20 µm-40 µm range particles seem to be the predominant component in the river water. Greater than 40 µm size particles (40 µm->88 µm) were only 26%. Particle sizes less than 3 µm existed only in the 6.5-8% range.

Bacterial analyses of these different particle ranges are also indicated in Table 1. It is apparent from the data that 20 µm-40 µm particles range contained the highest bacterial densities (8.3 x 10^5/ml) relative to other fractions. 40 µm-64 µm fraction contained slightly less (6.8 x 10^5/ml). Fractions 8 µm-20 µm and 64 µm-88 µm showed somewhat similar but lower bacterial content (3.6 to 3.7 x 10^5/ml). The adsorption response of different particle sizes to model contaminants are shown in Figure 2. It is apparent from the data that the predominant organic rich fraction 20 µm-40 µm clearly exhibited the greatest contaminant binding affinity. The rate of contaminant adsorption by these different particles (Figure 3) indicate that during the first 24 h period, a maximum removal occurred. The half-life of these dye solutions is from several hours to a few days.

The above results suggest that the contaminant binding efficiency in the Yamaska River suspended particles is controlled mostly by the organic content rather than the physico-chemical forces acting on the surface of the particles normally believed to be the controlling factor in the adsorption process. If the surface forces were the controlling factor, then the finest fraction (3-8 µm) should show the greatest binding efficiency.

The abundance of bacterial density in the predominant size fraction of the suspended particles is also interesting. This means that the bulk of the contaminant transport is associated with the predominant size fraction and models of contaminant transport should focus their attention on the transport characteristics of predominant size fraction.

It will be interesting to investigate whether the association of highest organic content with the predominant size fraction of suspended matter observed in the Yamaska River can be generalized to other rivers. If it can be generalized then it will have significant implication in the modelling of contaminant transport associated with the suspended particles in river systems. This aspect will be investigated in the future.

In this work we have not investigated the role of the much smaller colloidal particles which passed through the 3 μm filter during the fractionation process. It is likely that these particles have a role in the contaminant adsorption process as well. The nature and extent of the role of colloidal fraction in the Yamaska River needs to be investigated.

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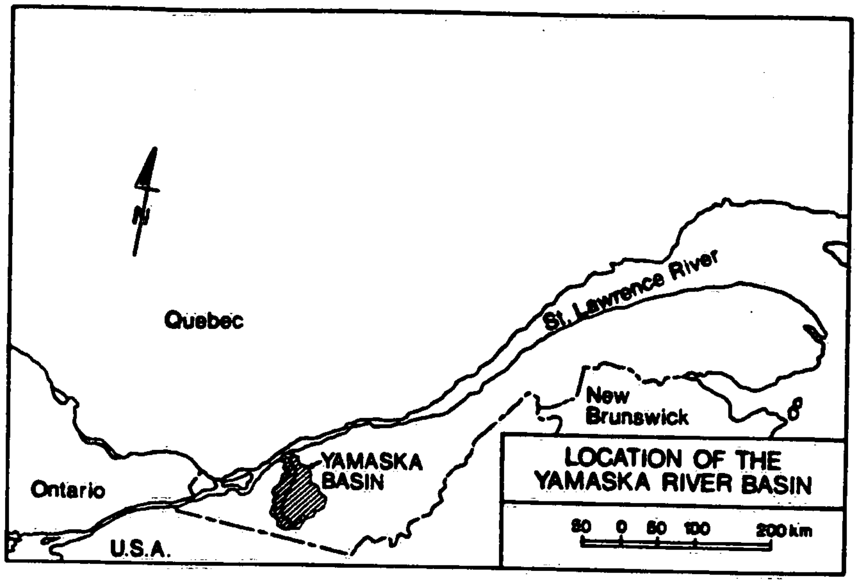
Table 1. Particle size distribution as measured by Malvern Particle Size Analyzer in Yamaska River.

Particle Size Range* (μ)	Bacterial densities ($x10^5$/mL)	% by volume in the river water	June		August		Average (% vol)
3 - 8	3.5		24.7		12.4		18.5
8 - 20	3.7	76.5	21.9	57.7	18.5	67	20.2
20 - 40	8.3		29.9		26.8		28.0
40 - 64	6.8		11.0		16.4		13.7
64 - 88	3.6	17.8	3.5	34.3	9.8	26	6.6
>88	-		3.3		8.1		5.7
			93.5		92.0		
<3 μ (%)			6.5		8.0		



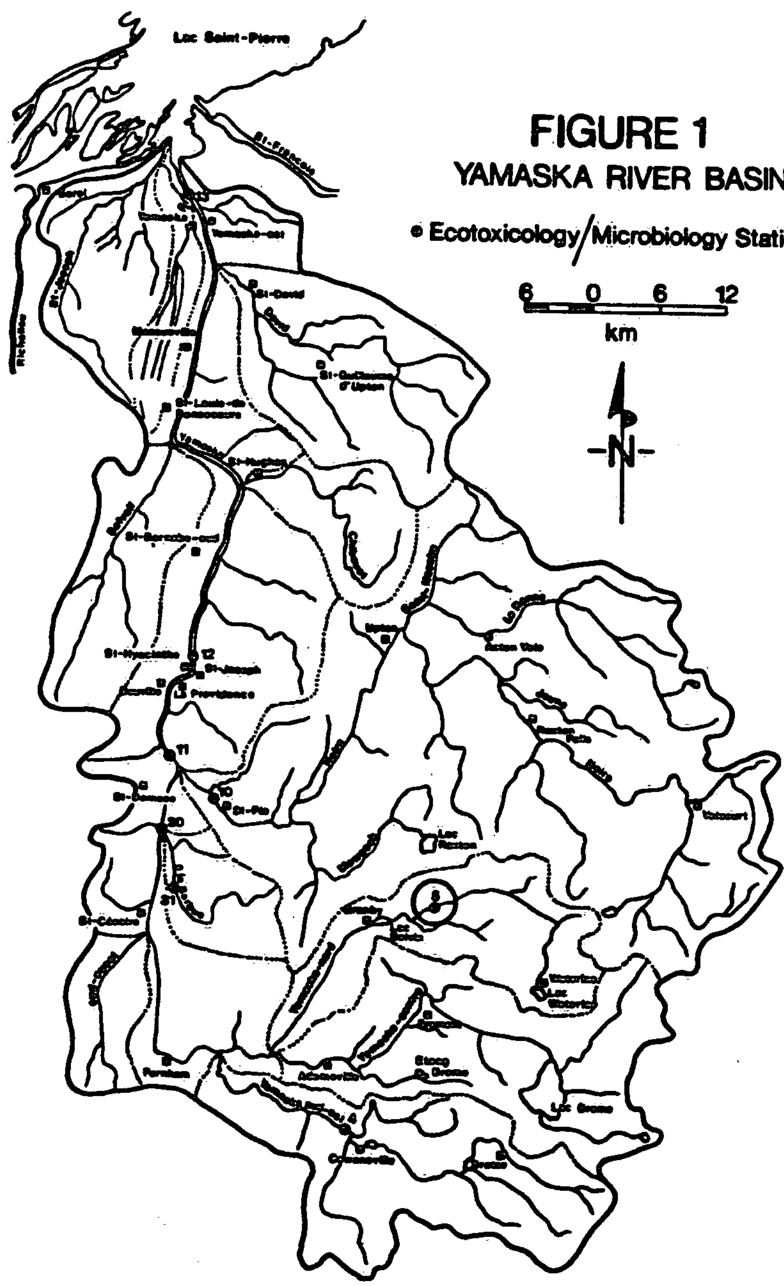


FIGURE 1
YAMASKA RIVER BASIN
• Ecotoxicology/Microbiology Stations

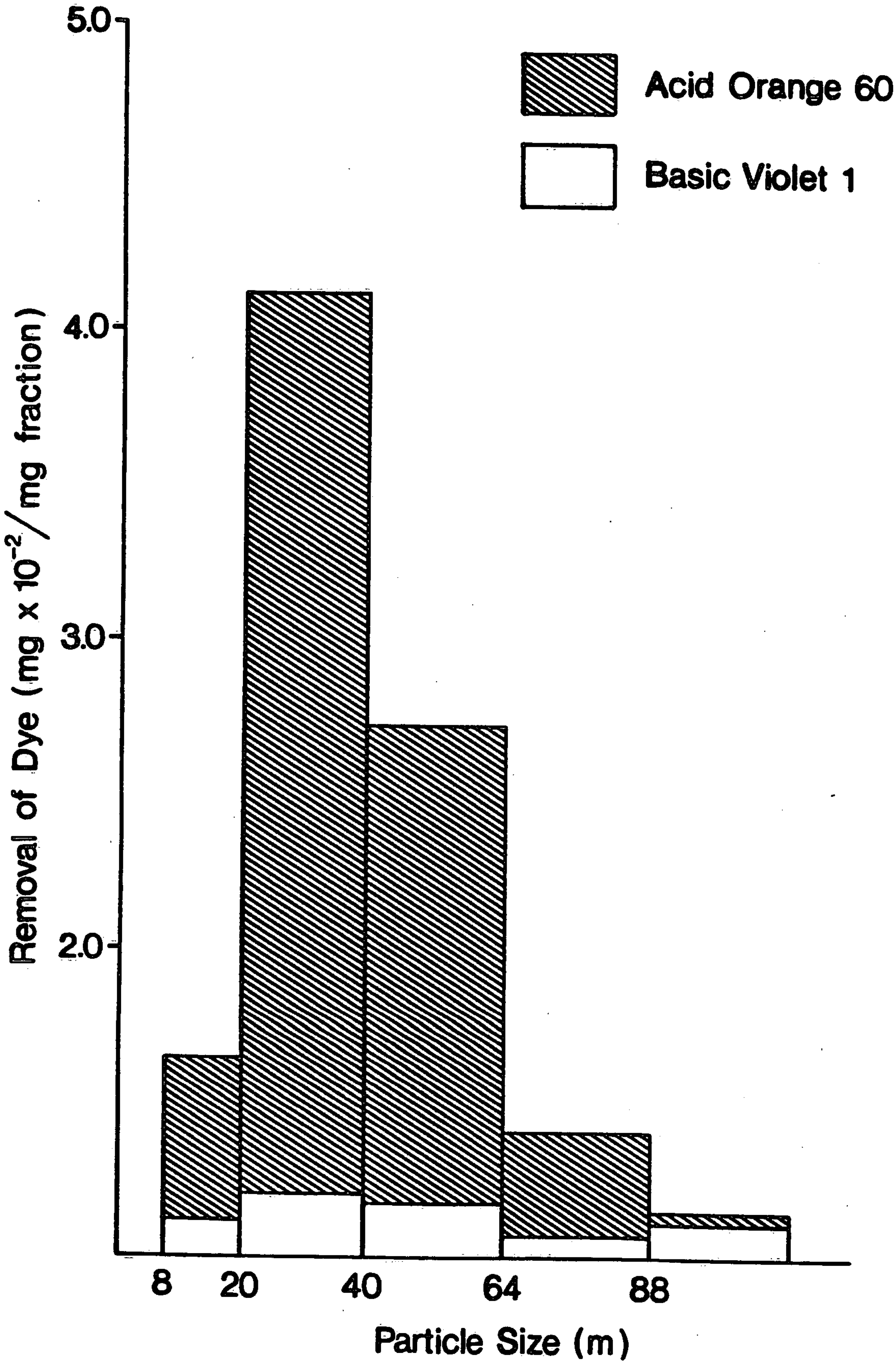


Fig. 2 Effect of Particle size on the contaminant dye removal in the Yamaska River (24 hr)

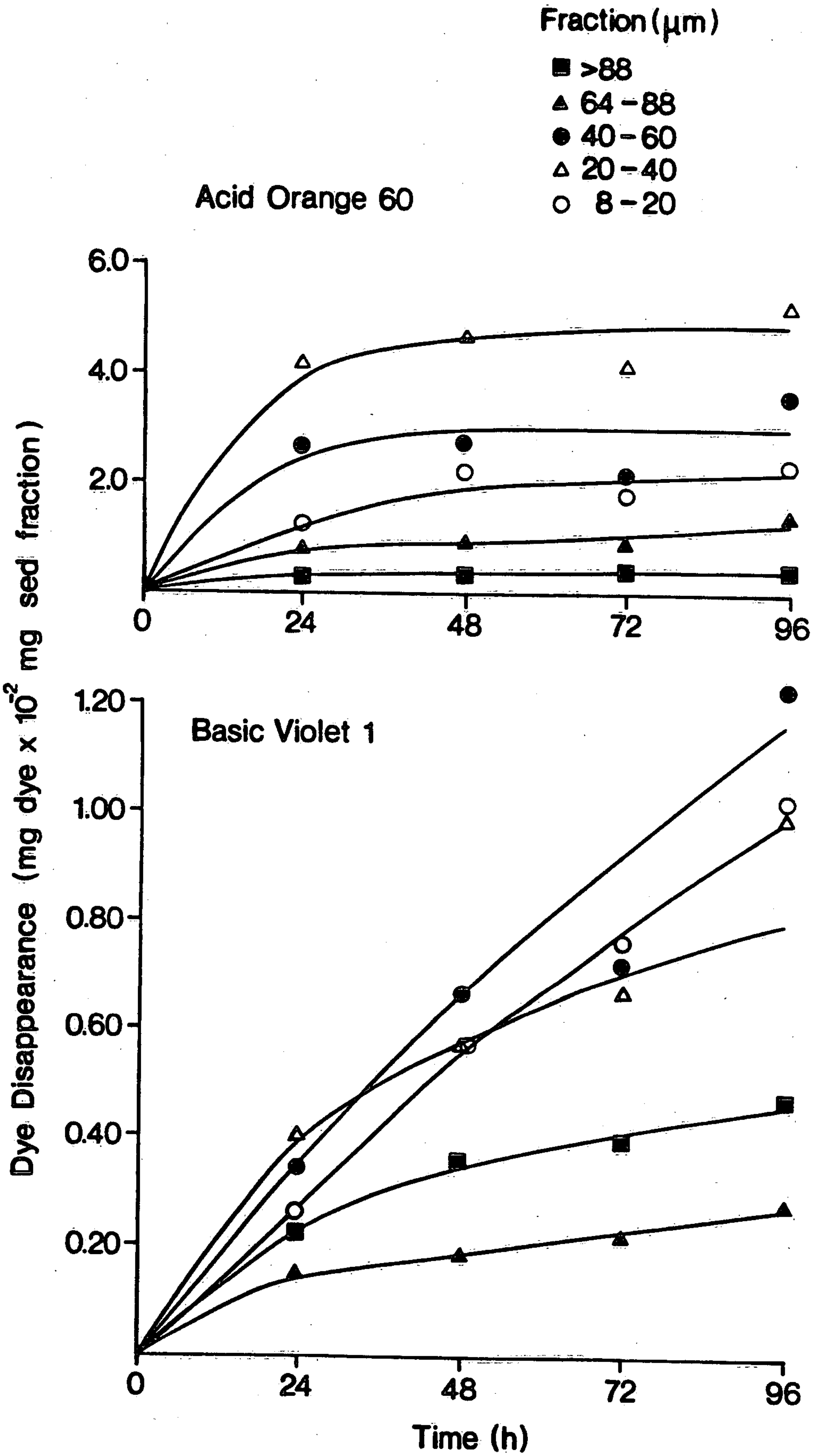


Fig.3 Effect of Particle size on the contaminant dye removal in the Yamaska River